

# Trends in Solid Tumor Incidence in Ukraine 30 Years After Chernobyl

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**PURPOSE** There is limited knowledge of the long-term health effects of the Chernobyl nuclear power plant accident that occurred more than 30 years ago in Ukraine. This study describes trends in the incidence of solid organ malignancy in Ukraine and the five regions most affected by the radioactive fallout.

**METHODS** The National Cancer Registry of Ukraine was queried for age-standardized incidence rates (ASIRs) of solid organ malignancy in Ukraine and the regions of Kyiv, Chernihiv, Zhytomyr, Rivne, and Volyn covering the period of 1999 to 2016. Joinpoint analysis was used to calculate the average annual percentage of change.

**RESULTS** The highest burdens of cancer incidence in Ukraine were seen in the lung, stomach, breast, and prostate. We observed significant increases in the ASIRs of colon (average annual percentage of change, 1.5 [95% CI, 1.3 to 1.7]), rectal (0.9 [95% CI, 0.6 to 1.2]), kidney (2.3 [95% CI, 1.8 to 2.9]), thyroid (4.2 [95% CI, 3.1 to 5.3]), breast (1 [95% CI, 0.6 to 1.4]), cervical (0.7 [95% CI, 0.3 to 1.2]), and prostate (3.9 [95% CI, 3.6 to 4.2]) cancers, with decreases in stomach (−2.4 [95% CI, −2.5 to −2.3]) and lung (−1.8 [95% CI, −2.1 to −1.5]) cancers. ASIRs in the affected regions were similar to nationwide rates, with the exception of those for Kyiv.

**CONCLUSION** The incidence rates of many solid organ malignancies in Ukraine are rising. However, the rates of solid organ malignancy in the five regions most affected by fallout did not substantially differ from national patterns, with the exception of those for Kyiv. Ongoing monitoring of cancer incidence in Ukraine is necessary to understand how best to decrease disease burden nationwide and to elucidate the causes of regional variations in ASIRs, such as access to diagnostics and environmental exposures.

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## INTRODUCTION

More than 30 years have passed since the 1986 Chernobyl nuclear power plant accident in Ukraine. Radioactive contamination from the explosion contaminated much of northern Europe, with the bulk of the fallout in Ukraine, Belarus, and the Russian Federation.<sup>1</sup> Notable contaminants included radioiodines, such as <sup>131</sup>I, and cesium isotopes, Cs-134 and <sup>137</sup>Cs.<sup>2</sup> Given the known effects of ionizing radiation on cancer (particularly lung, breast, stomach, bladder, and renal cancers and leukemia), there has been much discussion surrounding the long-term effects of radiation from Chernobyl on the incidence of cancer in Europe.

Most epidemiologic studies have focused on the effect of exposure to radioactive <sup>131</sup>I on thyroid cancer; it is now well documented that children and adolescents exposed to radioactive <sup>131</sup>I after the accident had a dose-related increase in risk of thyroid cancer.<sup>3,4</sup> This can be attributed to the ingestion of foods contaminated by <sup>131</sup>I<sup>1</sup>; however, the increased population incidence of

thyroid cancer in Ukraine, Belarus, and part of Russia may also be a reflection of increased medical monitoring and diagnosis in the wake of the accident.<sup>5</sup> Because of the elevated risk of leukemia among survivors of the atomic bombings in Japan, there has also been considerable interest in the incidence of hematologic malignancies after Chernobyl, but studies have found little to no evidence of an increase in childhood and adult leukemias,<sup>1</sup> apart from a small population of Chernobyl liquidators.<sup>6</sup>

As for nonthyroid solid cancers, the effect of radiation from Chernobyl is less certain.<sup>7</sup> There has been a general paucity of studies on nonthyroid solid cancers, which may be in part because of the long minimal latency period of radiation-induced solid cancers, in the magnitude of decades, compared with a minimum of 4 years for thyroid cancer and 2 to 7 years for leukemias.<sup>1,8,9</sup> Many factors, including screening practices and additional environmental exposures, may contribute to the evolving trends in cancer incidence in this region. For instance, there may have been increased

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interest in cancer risk after Chernobyl, resulting in increased incidence rates secondary to more detection, reporting, and diagnosis.<sup>10</sup> The National Cancer Registry of Ukraine (NCRU)<sup>11</sup> is a population-based database that monitors cancer incidence and mortality and represents a network of cancer registries based on Ukraine's administrative regions.<sup>12</sup> Despite the NCRU's existence for more than 20 years, there remains a paucity of literature on cancer epidemiology in Ukraine, which may be a result of the low global visibility of registries from countries in the former Soviet Union.<sup>13</sup>

The aim of this study was to describe the trends in the incidence of solid organ malignancy among men and women in Ukraine and to examine the incidence in the five regions most affected by the Chernobyl accident: Kyiv, Chernihiv, Zhytomyr, Rivne, and Volyn (Fig 1).

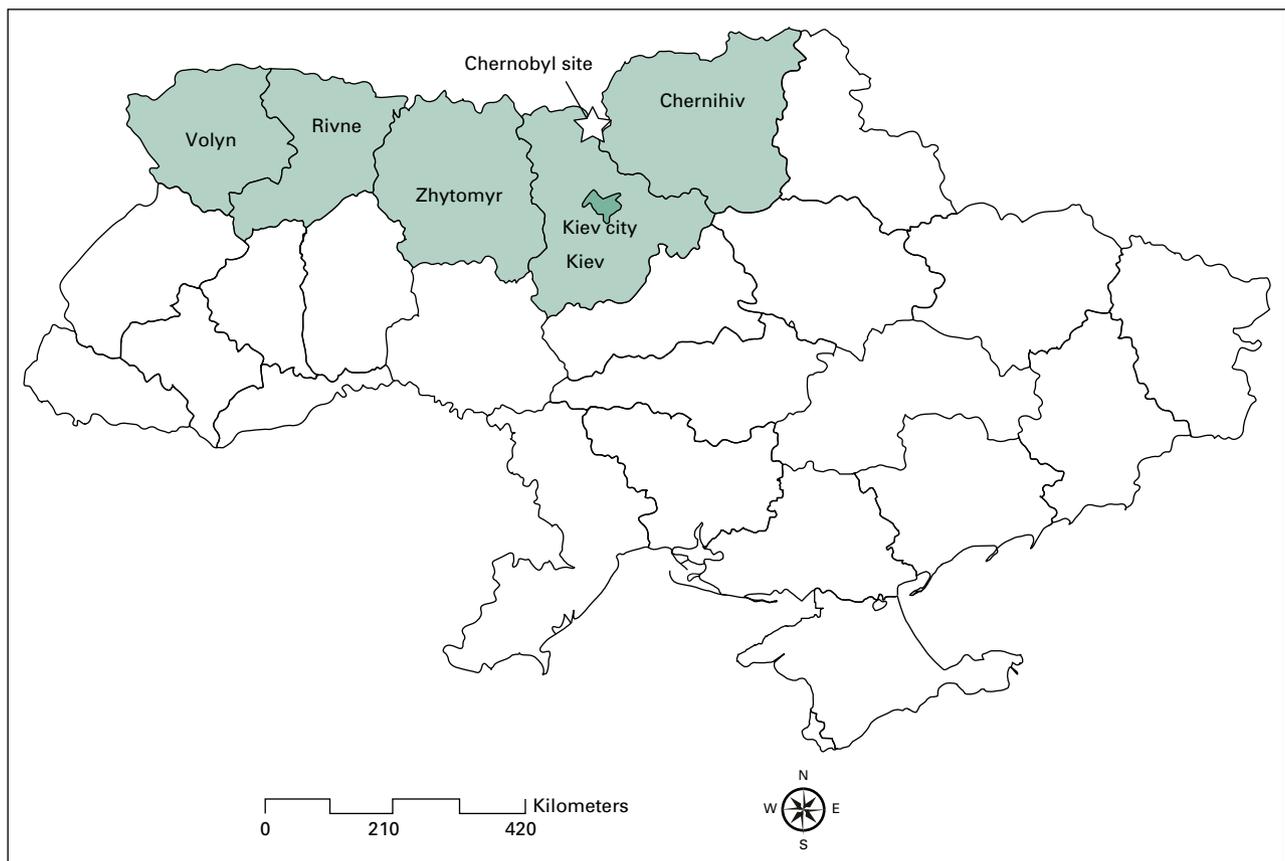
## METHODS

### Data Source

This is a descriptive study of solid tumor incidence trends in Ukraine from 1999 to 2016. We queried the database of the NCRU for incidence rates of solid organ malignancy. The NCRU is a population-based registry that depends on mandatory reporting of cancer diagnoses by local medical practitioners to regional administrators.<sup>12</sup> The data

collected by each Ukrainian administrative region are then submitted to the NCRU. Established in 1988, the database had reached near-universal coverage by 1997, and since 1999, the NCRU has published an annual report that includes data by region and Ukraine at large. Ryzhov et al<sup>13</sup> recently published a report on the quality of the data in the NCRU from 2002 to 2012, and they found its incidence and mortality data to be in accordance with international cancer registry standards with respect to timeliness, completeness, validity, and comparability. Specifically, there was uniform data collection, analysis, and timely reporting (cases entered in the same year of diagnosis) across all 27 regional registries.

We specifically used the age-standardized incidence rates (ASIRs) per 100,000 people, which were based on the Ukrainian standard. We gathered data for both the whole nation of Ukraine and for the regions of Kyiv, Chernihiv, Zhytomyr, Rivne, and Volyn, which were most affected by the Chernobyl accident (Fig 1). The specific topography examined included esophageal, stomach, colon, rectal, pancreatic, lung, kidney, bladder, brain, and thyroid in both sexes, as well as breast, cervical, and ovarian in women and prostate in men. Of note, the database did not distinguish between rectal and anal cancers, and these were recorded in a single category; furthermore, data on pancreatic cancer were not collected until 2002.



**FIG 1.** Map of Ukraine and the five regions most affected by the Chernobyl accident. Adapted from Melnitchouk et al<sup>14</sup> and the Humanitarian Data Exchange.<sup>15</sup>

## Statistical Analysis

Joinpoint regression analysis (<https://surveillance.cancer.gov/joinpoint/>, version 4.6.0.0) from the Surveillance Research Program of the National Cancer Institute) was used to analyze trends in ASIRs. The software calculated an estimated average annual percentage of change (AAPC) over this 18-year interval and allowed for comparison between AAPC values by region and sex for each cancer. A *P* value of < .05 was deemed significant.

## RESULTS

### Incidence Trends Across Ukraine

In this 18-year period, general trends were observed across Ukraine as a whole (Fig 2, Table 1). Of the 14 solid cancers included in this study, ASIRs were highest in the lung, stomach, breast (women only), and prostate (men only). Incidence rates of cancer were consistently higher in men than in women, with the exception of thyroid cancer, which was higher in women. A more than five-fold difference in incidence rate between sexes was noticed for esophageal, lung, and bladder cancers, with a near two-fold difference for stomach, rectal, pancreatic, kidney, and thyroid cancers.

There were statistically significant increases in the incidence rates of colon (AAPC, 1.5 [95% CI, 1.3 to 1.7]), rectal (0.9 [95% CI, 0.6 to 1.2]), kidney (2.3 [95% CI, 1.8 to 2.9]), and thyroid (4.2 [95% CI, 3.1 to 5.3]) cancer, with significant decreases in stomach (−2.4 [95% CI, −2.5 to −2.3]) and lung (−1.8 [95% CI, −2.1 to −1.5]) cancer for all Ukrainians, for men and women combined. Incidence rates of breast (1 [95% CI, 0.6 to 1.4]) and cervical (0.7 [95% CI, 0.3 to 1.2]) cancers in women and prostate (3.9 [95% CI, 3.6 to 4.2]) cancer in men also increased significantly.

### Differences by Region

ASIRs in individual regions were comparable to the ASIRs for all of Ukraine, but certain regions stood out (Fig 3, Table 1). Kyiv frequently had higher incidence rates than the other four regions. This was observed in all cancers combined and for cancers of the stomach, colon, lung, bladder, thyroid, and breast. These rates were generally comparable to Ukraine's national average, with the exception of thyroid cancer incidence rates, which were twice the rate of that of the overall nation. Interestingly, the incidence rates of thyroid cancer in Volyn were two-fold lower than those for all of Ukraine; rates of pancreatic and lung cancers in Volyn were also lower than the national rates. The rate of prostate cancer was higher in Volyn from 1999 to 2013.

The AAPCs in individual regions were generally similar to the AAPCs for all of Ukraine, with a few notable exceptions. Although the esophageal cancer incidence did not significantly change nationwide, regional analysis showed a modest yet statistically significant decrease in Kyiv over the 18-year interval (−1.4 [95% CI, −1.8 to −0.1]), which was driven primarily by a decrease in incidence rates in men. Likewise, although pancreatic cancer rates were

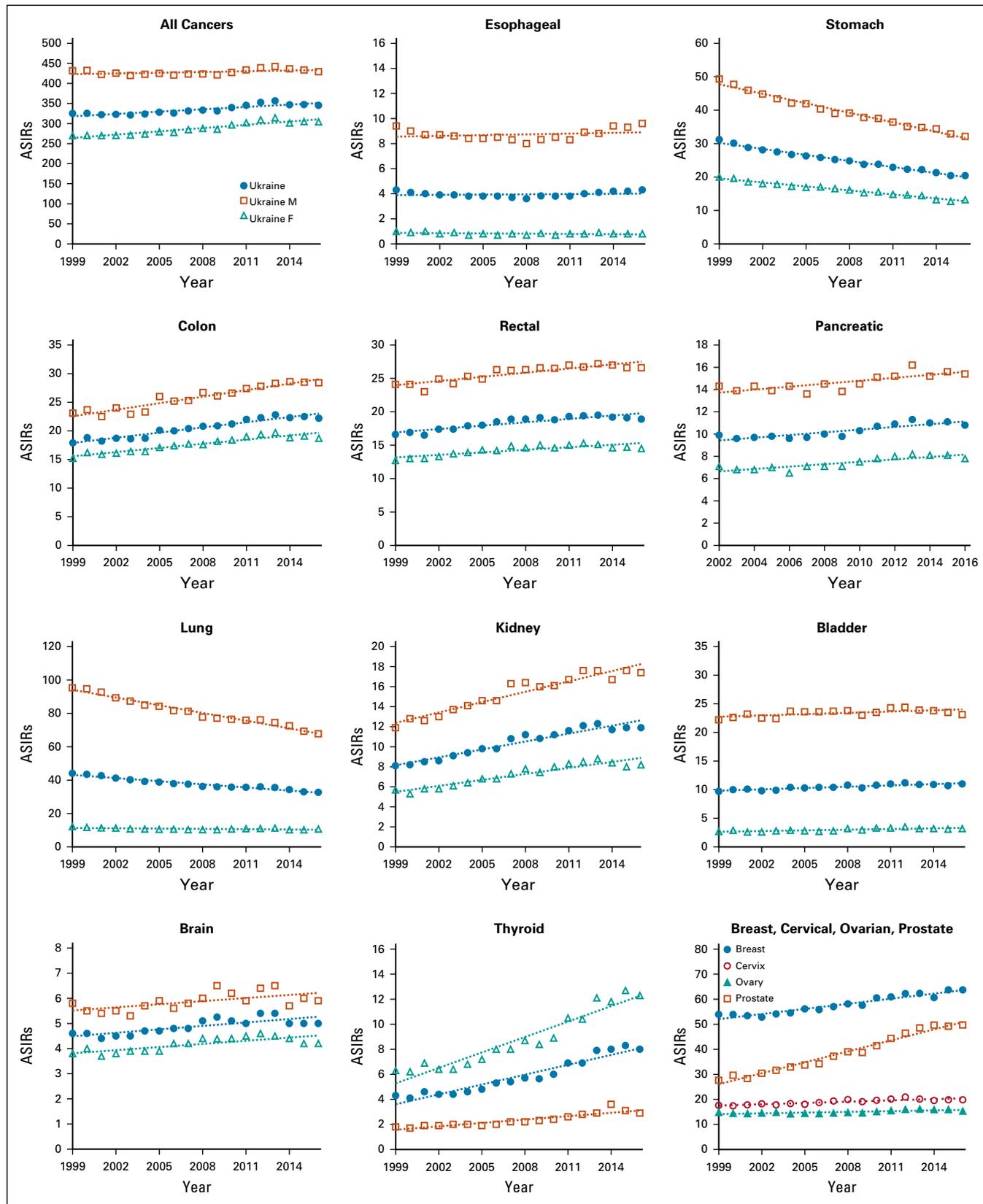
either stable to minimally increasing in Ukraine, there was a sharp, significant increase in Volyn (7 [95% CI, 1.8 to 12.5]) for both men (4.5) and women (9.1). Brain cancer incidence rates also increased in Volyn (2.9 [95% CI, 0.3 to 5.5]), particularly in women, and decreased in Zhytomyr (−2.3, [95% CI, −4.4 to −0.1]), again mostly in women, while remaining stable elsewhere.

## DISCUSSION

Our study used data from the NCRU to assess trends in solid organ tumor incidence in Ukraine from 1999 to 2016 and regional variations in five areas surrounding Chernobyl. We found that nationwide, many cancers exhibited clear sex-based differences in incidence rates with typically higher rates seen in men compared with women, with the exception of thyroid cancer. Although ASIRs for total malignancy burden were stable over this 18-year interval, ASIRs for stomach and lung cancers decreased markedly, whereas ASIRs for thyroid, kidney, colon, female breast, and male prostate cancers increased.

These trends are comparable to cancer trends in neighboring countries also in close proximity to the Chernobyl accident. Review of the International Agency for Research on Cancer database<sup>16,17</sup> indicates that Belarus (an Eastern European neighbor country north of Ukraine that was also affected by the Chernobyl accident) showed a similar decrease in ASIRs of stomach cancer and an increase in thyroid, kidney, colon, breast, and prostate cancers. Although the absolute ASIR values cannot be compared from country to country because of differences in cancer reporting and age standardization, the fold-difference between incidence rates in men and women was also observed in Belarus. Belarus showed similarly strong sex-based differences for esophageal, lung, and bladder (more than five-fold higher in men) cancers, as well as for stomach, pancreatic, kidney, and thyroid cancers (two- to five-fold in men, except in the case of thyroid cancer).

The majority of cancer trends in Ukraine were also mostly comparable to those in the United States in terms of direction of change,<sup>17</sup> although notable decreases in colon and cervical cancer incidence have occurred in the United States, whereas mild increases were observed in Ukraine. This may reflect the presence of screening programs, including Pap smears and colonoscopies, that catch premalignant lesions, which were in clinical use long before 1999 in the United States.<sup>18,19</sup> Otherwise, the decrease in stomach cancer incidence rates in Ukraine, much like in Belarus and the United States, may reflect globally improving hygiene together with decreased *Helicobacter pylori* exposure,<sup>20</sup> whereas the decrease in lung cancer may reflect a decrease in smoking and air pollution. However, because the majority of nationwide efforts to curb smoking in Ukraine started in 2005 and we expect a 5- to 15-year lag in lung cancer incidence,<sup>21</sup> a steeper drop in lung cancer incidence rates (closer to that observed in the United States) may be seen in the near future.



**FIG 2.** Trends in incidence of cancer in Ukraine from 1999 to 2016. The Ukrainian age-standardized incidence rates (ASIRs) shown are for all residents of Ukraine (male [M] and female [F] combined), with the exception of breast, cervical, and ovarian cancer, which reflect data from women only, and prostate cancer, which reflects data from men only. Average annual percentage of change is represented graphically as a linear regression of each data set.

TABLE 1. Cancer Trends Across the Ukraine from 1999 to 2016

Location	All			Esophageal			Stomach			Colon			Rectal		
	AAPC	95% CI	P	AAPC	95% CI	P	AAPC	95% CI	P	AAPC	95% CI	P	AAPC	95% CI	P
Ukraine															
All	0.3	0.1 to 0.5	<.05	0.2	-0.1 to 0.5	.2	-2.4	-2.5 to 2.3	<.05	1.5	1.3 to 1.7	<.05	0.9	0.6 to 1.2	<.05
Men	-0.1	-0.3 to 0.2	.6	0.3	-0.1 to 0.7	.2	-2.4	-2.6 to -2.2	<.05	1.5	1.2 to 1.8	<.05	0.8	0.6 to 1.1	<.05
Women	0.8	0.1 to 1.4	<.05	-1	-2.6 to 0.7	.2	-2.4	-2.7 to -2.2	<.05	1.1	0.8 to 1.5	<.05	0.8	0.5 to 1.2	<.05
Volyn															
All	0.4	-0.1 to 1	.1	1.8	0.6 to 3.1	<.05	-1.8	-2.7 to -0.9	<.05	3.5	2.7 to 4.4	<.05	1.3	0.3 to 2.4	<.05
Men	0.5	0.2 to 0.8	<.05	1.6	0.4 to 2.8	<.05	-1.9	-2.9 to -0.8	<.05	3.6	2.7 to 4.6	<.05	2.2	0.7 to 3.7	<.05
Women	0.4	-0.4 to 1.2	.3	2.9	-16.4 to 27	.8	-1.8	-3.1 to -0.5	<.05	3.5	2.2 to 4.8	<.05	0.5	-0.9 to 1.9	<.05
Zhytomyr															
All	0.7	0.3 to 1.1	<.05	-0.6	-2.3 to 1.1	.4	-2.5	-3.2 to -1.9	<.05	3.3	2.3 to 4.3	<.05	1	0.4 to 1.6	<.05
Men	-0.1	-0.9 to 0.7	.8	-0.4	-2.1 to 1.2	.6	-2.5	-3 to -1.9	<.05	3.7	2.6 to 4.9	<.05	0.7	-0.3 to 1.8	.2
Women	1.3	0.7 to 1.9	<.05	-2.7	-6.6 to 1.3	.2	-2.7	-3.7 to -1.6	<.05	2.7	1.5 to 3.9	<.05	1.2	0.4 to 2	<.05
Kyiv															
All	0.2	0 to 0.5	.1	-1.4	-2.8 to -0.1	<.05	-3.1	-3.4 to -2.7	<.05	1.5	1.1 to 1.9	<.05	0.4	-0.2 to 0.9	.2
Men	-0.4	-0.8 to 0	.1	-1.6	-3.1 to -0.2	<.05	-3.2	-3.7 to -2.8	<.05	1.3	0.6 to 2	<.05	0.6	-0.1 to 1.4	.1
Women	0.8	0.3 to 1.3	<.05	-1.9	-5 to 1.3	.2	-2.9	-3.5 to -2.3	<.05	1.6	1 to 2.2	<.05	0	-0.8 to 0.8	1
Rivne															
All	0.6	0.4 to 0.9	<.05	1.6	0.2 to 3.1	<.05	-1.5	-2.1 to -0.9	<.05	2.3	1.4 to 3.2	<.05	2.1	1 to 3.2	<.05
Men	0.1	-0.3 to 0.5	.5	1.7	0.3 to 3.1	<.05	-1.1	-1.8 to -0.3	<.05	2.4	0.8 to 4	<.05	1.6	0.5 to 2.8	<.05
Women	1.2	0.8 to 1.6	<.05	-1.9	-5 to 1.4	.2	-2.1	-3.2 to -1	<.05	2.5	1.2 to 3.7	<.05	2.8	1.4 to 4.3	<.05
Chernihiv															
All	0.7	0.1 to 1.3	<.05	0.5	-0.8 to 1.9	.4	-1.6	-2.2 to -0.9	<.05	3.1	2.2 to 4	<.05	1.5	1.1 to 1.9	<.05
Men	0.7	0.3 to 1	<.05	0.7	-0.7 to 2.1	.3	-1.4	-2.2 to -0.6	<.05	3.1	2.1 to 4.2	<.05	1.4	0.8 to 2	<.05
Women	1.1	0.5 to 1.7	<.05	0.3	-6.5 to 7.5	.9	-1.8	-2.6 to -1.1	<.05	3.1	2 to 4.3	<.05	1.6	0.7 to 2.6	<.05
Pancreatic															
Lung															
Kidney															
Bladder															
Brain															
Ukraine															
All	0.8	0 to 1.6	.1	-1.8	-2.1 to -1.5	<.05	2.3	1.8 to 2.9	<.01	0.7	0.5 to 0.9	<.05	0.6	-0.1 to 1.4	.1
Men	0.9	0.5 to 1.3	<.05	2.1	-2.4 to -1.8	<.05	2.3	1.8 to 2.9	<.05	0.2	-0.2 to 0.6	.4	0.7	0.2 to 1.2	<.05
Women	0.8	-0.2 to 1.8	.1	-0.7	-1.3 to -0.1	<.05	2.3	1.5 to 3.2	<.05	1.4	0.8 to 1.9	<.05	0.7	0 to 1.4	<.05
Volyn															
All	7	1.8 to 13	<.05	-1.9	-2.5 to -1.2	<.05	3.9	2.6 to 5.2	<.05	2.7	1.3 to 4.1	<.05	2.9	0.3 to 5.5	<.05
Men	4.5	2.1 to 6.9	<.05	-2.3	-3 to -1.6	<.05	4	2.5 to 5.5	<.05	2.6	1 to 4.3	<.05	1.9	-1.2 to 5.1	.2

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**TABLE 1.** Cancer Trends Across the Ukraine from 1999 to 2016 (Continued)

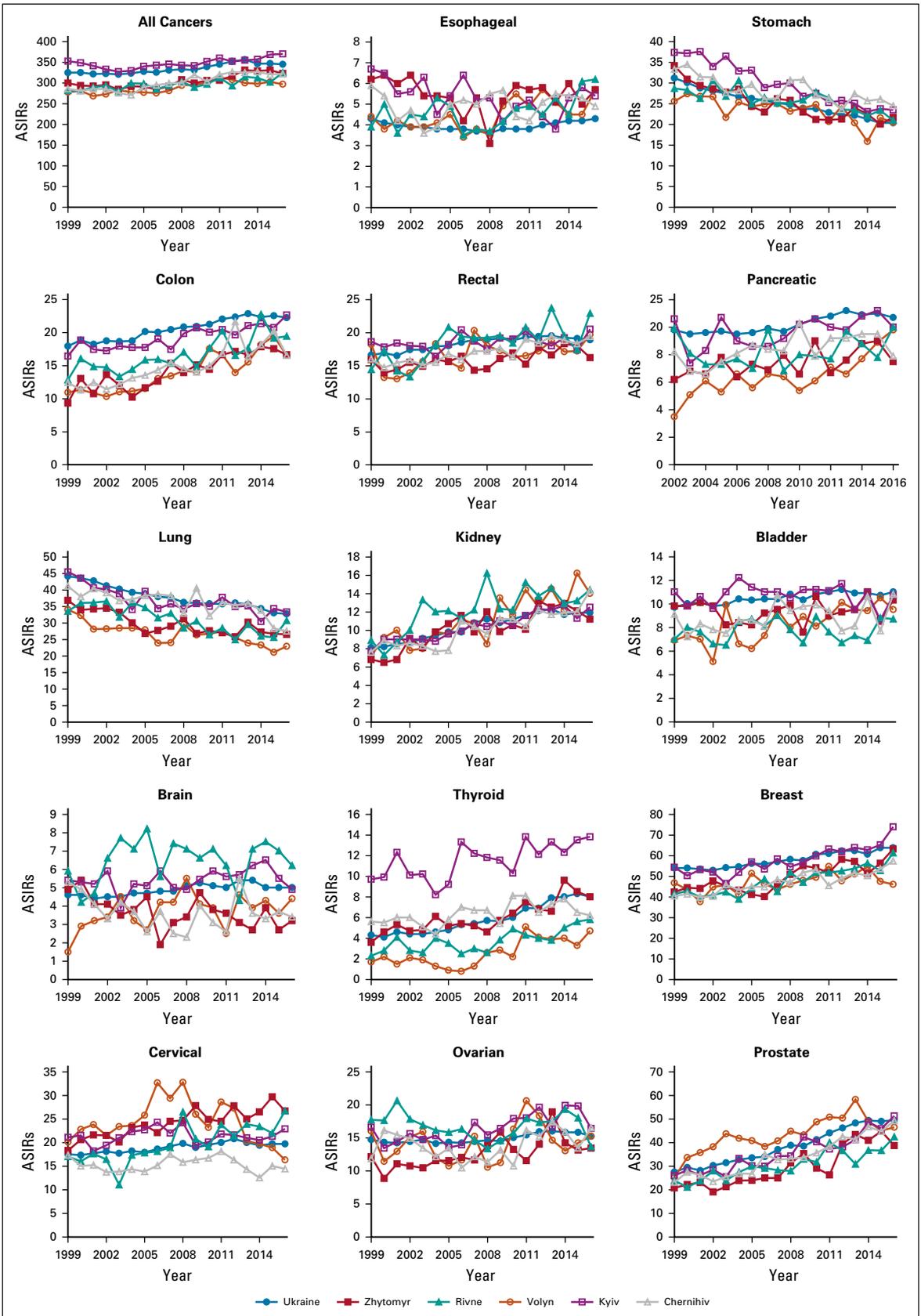
Location	AAPC	95% CI	P	AAPC	95% CI	P	AAPC	95% CI	P	AAPC	95% CI	P			
Women	9.1	1.7 to 17	< .05	0.8	-2.4 to 4.1	.6	4.1	2.6 to 5.7	< .05	3	-0.6 to 6.9	.1	4.5	1.5 to 7.6	< .05
<b>Zhytomyr</b>															
All	1.7	0.4 to 3	< .05	-1.7	-2.3 to -1	< .05	4	1.9 to 6.1	< .05	0.2	-0.8 to 1.2	.7	-2.3	-4.4 to -0.1	< .05
Men	1.3	-0.5 to 3.1	.2	-2	-2.5 to -1.4	< .05	3.9	1.8 to 6.1	< .05	0.1	-0.9 to 1.2	.8	-2.1	-5 to 1	.2
Women	2.3	0.6 to 4.1	< .05	-0.8	-0.7 to 2.1	.6	3.6	1.9 to 5.3	< .05	-0.9	-2.7 to 0.8	.3	-2.6	-5.2 to 0	< .05
<b>Kyiv</b>															
All	1.4	0.1 to 2.8	< .05	-1.5	-2.1 to -0.9	< .05	2.6	2.1 to 3.1	< .05	-0.2	-1.1 to 0.6	.5	0.7	-0.4 to 1.8	.2
Men	1.6	-0.2 to 3.5	.1	-1.8	-2.4 to -1.3	< .05	2.6	2.1 to 3.1	< .05	-0.5	-1.4 to 0.2	< .05	0.8	-0.7 to 2.4	.3
Women	1.1	-0.5 to 2.7	.2	-0.4	-1.6 to 0.9	.5	2.8	1.9 to 3.7	< .05	0	-2.3 to 2.4	1	0.7	-0.6 to 2	.3
<b>Rivne</b>															
All	0.7	-1 to 2.4	.4	-1.9	-2.6 to -1.2	< .05	3	1.7 to 4.4	< .05	0.4	-0.7 to 1.5	.5	0.9	-1 to 2.8	.3
Men	0.7	-1.7 to 3.2	.6	-2.1	-2.7 to -1.5	< .05	2.8	0.8 to 4.9	< .05	0.6	-0.6 to 1.9	.3	0.9	-1.8 to 3.7	.5
Women	0.5	-1.9 to 2.8	.7	-1.1	-2.9 to 0.8	.2	3.4	1.6 to 5.3	< .05	0.3	-2.4 to 3.1	.8	0.9	-1 to 2.9	.3
<b>Chernihiv</b>															
All	1.7	0.4 to 3	< .05	-2.2	-3.8 to -0.6	< .05	3.2	2.4 to 4.1	< .05	1	-0.2 to 2.2	.1	-1.3	-3.6 to 1.1	.3
Men	-0.9	-5.6 to 4.1	.7	-2.5	-4.1 to -1	< .05	3.8	2.9 to 4.7	< .05	0.5	-0.5 to 1.6	.3	-2.1	-4.6 to 0.5	.1
Women	2.8	0.5 to 5.2	< .05	0	-1.6 to 1.5	1	2.6	0.9 to 4.3	< .05	2.8	-0.4 to 6	.1	-0.3	-3.6 to 3	.8
<b>Thyroid</b>															
<b>Breast</b>															
<b>Cervical</b>															
<b>Ovarian</b>															
<b>Prostate</b>															
<b>Ukraine</b>															
All	4.2	3.1 to 5.3	< .05												
Men	3	1.2 to 4.9	< .05										3.9	3.6 to 4.2	< .05
Women	4.3	3.1 to 5.5	< .05	1	0.6 to 1.4	< .05	0.7	0.3 to 1.2	< .05	0.3	-0.2 to 0.9	.2			
<b>Volyn</b>															
All	3.5	-5 to 13	.4												
Men	5.2	0.7 to 9.9	< .05										2.9	-0.7 to 6.7	.1
Women	5.4	-11.4 to 26	.6	1	0.2 to 1.8	< .05	-1	-2.9 to 1	.3	0.9	-0.9 to 2.8	.3			
<b>Zhytomyr</b>															
All	4.2	3 to 5.5	< .05												
Men	1.8	-1 to 4.6	.2										4.9	3.7 to 6.1	< .05
Women	4.6	3 to 6.3	< .05	1.5	-1.7 to 4.8	.4	2.1	1.5 to 2.7	< .05	2.2	1 to 3.5	< .05			
<b>Kyiv</b>															
All	2	0.8 to 3.1	< .05												
Men	2.8	0.9 to 4.8	< .05										4	3.2 to 4.7	< .05
Women	1.7	0.4 to 3.1	< .05	1.9	1.3 to 2.4	< .05	0.3	-0.5 to 1	.4	-0.8	-2.6 to 1.1	.4			

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**TABLE 1.** Cancer Trends Across the Ukraine from 1999 to 2016 (Continued)

Location	AAPC	95% CI	P	AAPC	95% CI	P	AAPC	95% CI	P	AAPC	95% CI	P
Rivne												
All	4.1	2.2 to 6.1	< .05									
Men	2.4	-0.9 to 5.9	.1				3.3	2.5 to 4.2				< .05
Women	4.6	1.9 to 7.5	< .05	2.3	1.7 to 2.9	< .05	3.1	1.7 to 4.5	< .05	-1.8	-4.3 to 0.8	.2
Chernihiv												
All	1.8	0.4 to 3.1	< .05									
Men	-0.8	-3.7 to 2.2	.6							4.5	3.8 to 5.2	< .05
Women	2.4	1.1 to 3.7	< .05	1.8	1.4 to 2.3	< .05	-0.7	-4.3 to 3	.7	0.8	-0.7 to 2.3	.3

Abbreviation: AAPC, average annual percentage of change.



**FIG 3.** Trends in cancer incidence in the regions of Volyn, Zhytomyr, Kyiv, Rivne, and Chernihiv. The Ukrainian age-standardized incidence rates (ASIRs) shown are for all residents of the regions (male [M] and female [F] combined), with the exception of breast, cervical, ovarian cancer, which reflect data from women only, and prostate cancer, which reflects data from men only.

Surprisingly, our calculated AAPC for thyroid cancer incidence rates in the nation of Ukraine from 1999 to 2016 was 4.2, which was not particularly different from the 3% to 4% observed in the United States SEER registry over a similar time interval.<sup>22</sup> That Ukraine did not have a substantially different AAPC for thyroid cancer may relate to the fact the effects of radiation are difficult to see at the population level.<sup>23</sup> The rate of increase in the United States is felt to reflect overdiagnosis, and it is difficult to determine the extent to which overdiagnosis in Ukraine is strictly a result of country-specific fears after Chernobyl or a more generalizable global phenomenon. We also acknowledge that the effect of radioactive iodine ingestion after Chernobyl was likely not captured in our data set, because thyroid cancer risk was seen in children born between 1982 and 1986,<sup>24</sup> and our data collection begins in 1999 and captures only adults.

Our analysis of the NCRU data by region also found that the rates of many cancers were highest in Kyiv. This is not unexpected because this region surrounds the administrative region that corresponds to the capital city, Kyiv. Although the data for the city of Kyiv (population, 2.9 million)<sup>25</sup> are separate from that of the Kyiv region (population, 1.7 million; 60% urban) for both administrative purposes and in NCRU data, it is possible that residents of the region have improved access to medical care in the capital city and outlying areas. In fact, a review of the NCRU database shows that ASIRs for certain cancers were often slightly higher in the city of Kyiv than in its surrounding region, which may suggest that high incidence rates are related to increased access to cancer diagnostics. Indeed, the health care system in Ukraine is largely state run, with additional private medical services that are based primarily around the city of Kyiv.<sup>13,23</sup> Of note, Zhytomyr, Rivne, Volyn, and Chernihiv have populations of 1 to 1.2 million, where less than 50% to more than 60% of their populations are classified as urban. This suggests that regional differences are not solely a result of broad differences between urban and rural medical care; rather, there may be something unique to the Kyiv region. This seems to be supported by a study of the Ukrainian health system by Peabody et al,<sup>23</sup> which found that regional variations in the quality of health care in Ukraine are not only present but are greater than the rural-urban differential seen in other countries.

Our analysis also found several regional differences in Volyn that are difficult to explain, including lower ASIRs of thyroid and lung cancer and higher ASIRs of prostate cancer when compared with the rest of Ukraine. Future work examining differences in the health system, demographics, and environmental exposures of different regions in Ukraine are needed to better elucidate why these differences exist.

Our study's primary limitation is caused by its dependence on data from the NCRU, which did not have robust available data before 1999. We also recognize that certain diagnostic codes were grouped in the NCRU data, such as

those for rectal and anal cancers (C19 to C21), which are considered separate cancers. However, these data are grouped together in other national cancer registries, and the quality of data in the NCRU from 2002 to 2012 was found to be in accordance with international cancer registry standards.<sup>13</sup> Of note, Ryzhov et al<sup>13</sup> does not comment on the data from 1999 to 2001 or after 2012 that we included, and indeed, we recognize that the data after 2012 are intermittently absent for certain regions because of political instability. Although the quality of these data has yet to be validated, NCRU reporting was nearly complete by 1997,<sup>12</sup> and we did not observe substantial changes in the trend of ASIRs for the whole nation of Ukraine at the 2001 or 2012 time points (Figs 2 and 3). This suggests that the absence of certain regions did not have a visible impact on the ASIRs and calculated AAPCs from 1999 to 2016.

Ultimately, there remains a great need to continue monitoring cancer trends in Ukraine, Belarus, and Russia from both a public health perspective and to monitor the long-term effects of radiation, not only from Chernobyl but also from active uranium processing facilities that have been associated with an increased incidence of lung, breast, kidney, and hematologic cancers.<sup>26</sup> Colorectal and cervical cancer screenings may relate to decreased incidence rates in the United States, but currently there are no equivalent screening programs in Ukraine. Although this may relate to limited funding in a developing country, cost-effectiveness studies suggest that these screening programs may be feasible.<sup>14,27,28</sup> Furthermore, a report from the World Bank<sup>21</sup> noted that cancer in Ukraine is marked by extremely high lethality, particularly among people under the age of 65 years. There may even be a role for lung and breast cancer screening because, despite the downtrending incidence rate of lung cancer, it continues to account for a large burden of cancer mortality in men, whereas mortality from breast cancer is rising in women.<sup>21</sup>

Incidence rates of solid tumors in Ukraine are subtly rising, with increases in colon, rectal, kidney, thyroid, breast, cervical, and prostate cancers and notable decreases in stomach and lung cancers. The effects of radiation from Chernobyl were not seen in the regional cancer registries for the five regions most affected by fallout; however, higher incidence rates were observed in the Kyiv region, which may reflect a concentration of resources around the city of Kyiv. National trends in cancer incidence rates for the nation of Ukraine are comparable to those observed in its neighbor country, Belarus, and are mostly comparable to those of the United States, with the exception of decreasing colon and cervical cancer rates in the United States. Additional work is needed to assess the feasibility and potential effects of widespread screening programs for these preventable cancers in Ukraine; furthermore, ongoing monitoring of regional variations not only in cancer incidence but also in mortality is required.

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## AUTHORS' DISCLOSURES OF POTENTIAL CONFLICTS OF INTEREST

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## REFERENCES

- Bennett B, Repacholi M, Carr Z, (eds): Health Effects of the Chernobyl Accident and Special Health Care Programmes: Report of the UN Chernobyl Forum Expert Group "Health". Geneva, Switzerland, World Health Organization, 2006
- United Nations Scientific Committee on the Effects of Atomic Radiation: UNSCEAR 2008 Report Vol. II: Sources and Effects of Ionizing Radiation. New York, NY, United Nations, 2011
- Jacob P, Bogdanova TI, Buglova E, et al: Thyroid cancer risk in areas of Ukraine and Belarus affected by the Chernobyl accident. *Radiat Res* 165:1-8, 2006
- Shakhtarin VV, Tsyb AF, Stepanenko VF, et al: Iodine deficiency, radiation dose, and the risk of thyroid cancer among children and adolescents in the Bryansk region of Russia following the Chernobyl power station accident. *Int J Epidemiol* 32:584-591, 2003
- Jargin SV: Chernobyl-related cancer and precancerous lesions: Incidence increase vs. late diagnostics. *Dose Response* 12:404-414, 2014
- Ivanov VK, Rastopchin EM, Gorsky AI, et al: Cancer incidence among liquidators of the Chernobyl accident: Solid tumors, 1986-1995. *Health Phys* 74:309-315, 1998
- Hatch M, Ostroumova E, Brenner A, et al: Non-thyroid cancer in Northern Ukraine in the post-Chernobyl period: Short report. *Cancer Epidemiol* 39:279-283, 2015
- Nikiforov YE: Radiation-induced thyroid cancer: What we have learned from Chernobyl. *Endocr Pathol* 17:307-317, 2006
- Peterson LE, Dreyer ZE, Plon SE, et al: Design and analysis of epidemiological studies of excess cancer among children exposed to Chernobyl radionuclides. *Stem Cells* 15:211-30, 1997
- Cardis E, Hatch M: The Chernobyl accident—an epidemiological perspective. *Clin Oncol (R Coll Radiol)* 23:251-260, 2011
- National Cancer Registry of Ukraine. <http://www.ncru.inf.ua>
- Ryzhov A, Fedorenko Z, Goulak L, et al: Cancer incidence trends in Ukraine, 2002-2012. ENCR Scientific Meeting and General Assembly, Luxembourg, October 5-7, 2016 (abstr)
- Ryzhov A, Bray F, Ferlay J, et al: Evaluation of data quality at the National Cancer Registry of Ukraine. *Cancer Epidemiol* 53:156-165, 2018
- Melnitchouk N, Shabat G, Lu P, et al: Colorectal cancer in Ukraine: Regional disparities and national trends in incidence, management, and mortality. *J Glob Oncol* 4:1-8, 2018
- Humanitarian Data Exchange: Ukraine administrative level 0, 1, 2, 3 and 4 boundaries, version 1.31.9. <https://data.humdata.org/dataset/ukraine-administrative-boundaries-as-of-q2-2017>
- Bray F, Colombet M, Mery L, et al (eds): Cancer Incidence in Five Continents, Vol. XI. Lyon, France, International Agency for Research on Cancer, 2017
- Ferlay J, Colombet M, Bray F: Cancer Incidence in Five Continents, CI5plus: IARC CancerBase No. 9. Lyon, France, International Agency for Research on Cancer, 2018
- Dewar MA, Hall K, Perchalski J: Cervical cancer screening. Past success and future challenge. *Prim Care* 19:589-606, 1992
- Winawer SJ: The history of colorectal cancer screening: A personal perspective. *Dig Dis Sci* 60:596-608, 2015
- Paik DC, Saborio DV, Oropeza R, et al: The epidemiological enigma of gastric cancer rates in the US: Was grandmother's sausage the cause? *Int J Epidemiol* 30:181-182, 2001
- World Bank: An Avoidable Tragedy: Combating Ukraine's Health Crisis. Lessons from Europe. Washington, DC, World Bank Group, 2009
- Lim H, Devesa SS, Sosa JA, et al: Trends in thyroid cancer incidence and mortality in the United States, 1974-2013. *JAMA* 317:1338-1348, 2017
- Peabody JW, Luck J, DeMaria L, et al: Quality of care and health status in Ukraine. *BMC Health Serv Res* 14:446, 2014
- Fuzik M, Pryszyzhnyuk A, Shibata Y, et al: Thyroid cancer incidence in Ukraine: Trends with reference to the Chernobyl accident. *Radiat Environ Biophys* 50:47-55, 2011
- Timonina MB (ed): Population of Ukraine 2016, Demographic Yearbook. Kyiv, Ukraine, State Statistics Service of Ukraine, 2017
- Bazyka DA, Pryszyzhnyuk AY, Romanenko AY, et al: Cancer incidence and nuclear facilities in Ukraine: A community-based study. *Exp Oncol* 34:116-120, 2012
- World Bank: Cervical Cancer in Ukraine: The Continuum of Care and Implications for Action (Ukrainian). Ukraine Continuum of Care Analyses - Breast Cancer, Cervical Cancer, Diabetes, Hypertension. Washington, DC, World Bank Group, 2019
- Melnitchouk N, Soeteman DI, Davids JS, et al: Cost-effectiveness of colorectal cancer screening in Ukraine. *Cost Eff Resour Alloc* 16:20, 2018

